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Table 24.2 Fillers for thermoplastic polymers[3]

Silica products
- Minerals
  - Sand
  - Quartz
  - Novaculite
  - Tripoli
- Diatomaceous earth
- Synthetic amorphous silica
- Wet process silica
- Fumed coloidal silica
- Silica aerogel

Silicates
- Minerals
  - Kaolin (China clay)
  - Mica
  - Nepheline silicate
  - Talc
  - Wollastonite
  - Asbestos
- Synthetic products
  - Calcium silicate
  - Aluminum silicate

Glass
- Glass flakes
- Hollow glass spheres
- Cellular glass nodules
- Glass granules or cullet

Calcium carbonate
- Chalk
- Limestone
- Precipitated calcium carbonate

Metallic oxides
- Zinc oxide
- Alumina
- Magnesia
- Titania
- Beryllium oxide
- Aluminum trihydrate

Other inorganic compounds
- Barium sulfate
- Silicon carbide
- Molybdenum disulfide
- Barium ferrite
- Mica

Metal powders
- Aluminum
- Bronze
- Lead
- Stainless steel
- Zinc

Carbon
- Carbon black
  - Channel black
  - Furnace black
- Ground petroleum coke
- Pyrolized products
- Intercalated/exfoliated graphite

Cellulosic fillers
- Wood flour
- Shell flour

Comminuted polymers

- Corollary I: Adding foam, fillers or reinforcements to neat polymers will never improve their processability.

24.2 RHEOLOGY, FIBER FLOW AND FIBER ORIENTATION

Rheology is the study of polymer flow. Shear flow and elongational flow dominate polymer processing. The great length of polymer chains results in extensive entanglements and complicates the study of neat polymer flow. The economic importance of polymer processing and the technical challenge of predicting molten polymer response to applied load have resulted in an incredibly rich literature[15–21]. Neat polymer melts are considered as viscoelastic non-Newtonian fluids. Viscosity is the measure of fluid resistance to applied load. The viscosities of oil and water are material constants, independent of shear rate. Fluids of this type are called Newtonian fluids. In steady-state shearing flow, polymers typically exhibit shear-dependent viscosities, as with

Handbook of Composite (2nd Edition) 1998

provide the desired overall performance, the process calls for a further reduction in paste viscosity. This may be accomplished by adding small amounts of diluents (0–5 phr), which also helps to improve the plastisol's shelf stability.

Fillers

The most widely used fillers in plastisols are calcium carbonate and aluminum trihydrate. Other fillers include calcium sulfate, barium sulfate, clay, mica, and precipitated silicas.

Most fillers come in various particle sizes, shapes, and particle size distributions. Fillers with a finer particle size distribution with high surface areas and more irregular shapes will afford higher paste viscosities. As the filler loading is increased, the plastisol viscosity is increased along with thixotropy, and the plastisol flow becomes more dilatant. Aluminum trihydrate is used as a flame retardant and as a smoke suppressant.

Fillers in general are added to impart weight in carpet tile formulations and to improve properties such as insulation resistance, UV resistance, scuff resistance, heat deformation, and gloss reduction. However, fillers also have negative effects on tensiles, elongation, cut-through resistance, moisture resistance, and electrical insulation; they may also introduce unwanted color into the product because of metal impurities present in the filler.

Pigment

Pigments are incorporated into the vinyl plastisol, primarily to impart a given color to the final product. Color is very important to the end-user, and as such becomes a major consideration for the plastisol formulator, whose concerns must go far beyond simply providing the desired shade and intensity of color to the customer. The formulator also must provide the right degree of opacity, a color that will not change, a product that will not degrade no matter what the end-use environment, a safe product, a high-value-versus-price product, and a product that can be safely and efficiently processed in the manufacturer's plant. Materials that can be used to impart color to a plastisol-based item can be divided into several classifications. The first division includes those materials that are soluble in the PVC polymer and enter into the polymer matrix just as the plasticizer does during the fusion process; these can be broadly defined as dyes. Those materials that are insoluble in the PVC and the plasticizer, and thus maintain their particle structure in the fused part, generally are referred to as pigments. Pigments can be either organic in nature or inorganic but must be insoluble in the plastisol system. Included in the inorganic family of pigments are lead, cadmium, chrome, and titanium salts and oxides, titanium dioxide being by far the most used of any colorant material. Carbon black is perhaps the most common organic pigment, with azo- and phthalocyanines being other well-known families of compounds. Some special-interest products include those that produce metallic, pearlescent, and fluorescent effects in the vinyl.[20]

Of great importance to the final customer is the life of the product—how long the polymer system will maintain its integrity, and how long the product's color will remain unchanged. Of special concern here will be the effects of heat during processing, whether the pigment itself changes on exposure to heat, and whether the PVC changes. Products intended for outside use must be resistant to sunlight and moisture.

The formulator must be aware of the pigment's effects on the polymer or other ingredients in the system, whether positive or negative. For example, titanium dioxide is more often included in the formulation because of its ability to reflect UV light, which would rapidly degrade the PVC, rather than for the color its produces. On the other hand, pigments containing iron could cause the PVC to degrade. If the pigment were susceptible to attack by chemicals in its end-use or processing environment, such as alkali, or by contaminants in the air, then degradation of either the pigment, the polymer, or both could occur.

Migration of the pigment or dye to the surface of the vinyl causes numerous problems. If the migration occurs during the processing of the plastisol, the pigment can plate out or deposit on the surface of the mold or other processing equipment. Slow migration of the dry